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THE UNITY OF PHYSICAL SCIENCE.*

THERE is a tradition, still tacitly sanctioned even by men of science, that there have been epochs when the more eminent minds were able to compass the entire range of knowledge. Amongst the vanishing heroic figures of the past it seems possible, indeed, to discern, here and there, a Galileo, a Huygens, a Descartes, a Leibnitz, a Newton, a Laplace or a Humbolt, each capable, at least, of summing up with great completeness the state of contemporary knowledge. Traditions, however, are generally more or less mythical, and the myth in this case seems to be in flat contradiction with the fact that there never was such an epoch, that the great masters of our distinguished predecessors were, after all, much like the masters of to-day, simply the leading specialists of their times. But however this may be, if we grant the possibility of the requisite attainments, even in a few individuals at any epoch, we shall speedily conclude that there never was an epoch so much in need of them as the immediate present, when the divisional speakers of this congress are called upon to explain the unities which pervade the ever-widening and largely diverse fields of their several domains.

The domain of physical science, concerning which I have the honor to address you to-day, presents peculiar and peculiarly formidable difficulties in the way of a summary review. While we may not be dis-

* Address before the Division of Physical Science, International Congress of Arts and Science, St. Louis, September 19–25, 1904.

posed to limit the wide range of inclusion specified by our program, we must at once disclaim any attempt to speak authoritatively with respect to most of its details. There is, in fact, such a vast array of knowledge now comprehended under any one of the six departments of our division, that the boldest author must hesitate to enter on a limited discussion with respect to any of them. But if it is thus difficult to consider any department of physical science, it appears incomparably more difficult to contemplate all of them in the bewildering complexity of their interrelations and in the bewildering diversity of their subject-matter. What, for example, could seem more appalling to the average man of science than the duty of explaining the connections of archeology and astrophysics or those of ecology and electrons?

Happily, however, the managers of the congress have provided an adequate division of labor, whereby the technical details of the various departments are allotted to experts, giving thus to a divisional speaker a degree of freedom with respect to depth in some way commensurate with the breadth of his task. Presuming, therefore, that I may deal only with the broader outlines and salient features of the subject, I invite your attention to a summary view of the present status and the apparent trend of physical science.

Whatever may be affirmed with respect to science in general, there appears to be no doubt that all of the physical sciences are characterized by three remarkable unities —a unity of origin, a unity of growth and a unity of purpose. Physical science originates in observation and experiment; it rises from the fact-gathering stage of unrelated qualities to the higher plane of related quantities, and passes thence on to the realm of correlation, computation and prediction under theory; and its purpose is to interpret in consistent and verifiable terms the universe, of which we form a part. The recognition of these unities is of prime importance; for it helps us to understand and to anticipate a great diversity of perfection amongst the different branches of science, and hence leads us to appreciate the desirability of hearty cooperation on the part of scientific workers in order that progress may be ever positive towards the common goal.

Glancing rapidly seriatim at the different departments of physical science as specified by our program, we come first to a consideration of formal physics, and we may most quickly orient ourselves aright in this department by trying to state in what respects the physics of to-day differs from the physics of a hundred years ago.

In spite of the extraordinary perfection of the work of Lagrange, Laplace, Fourier, Young, Fresnel, Poisson, Green, Gauss and others of the early part of the nineteenth century, it will be at once admitted that great progress has been made. In addition to noteworthy advances and improvements along the lines laid down by these masters, there have been developed the relatively new fields of elasticity, electromagnetics, thermodynamics and astrophysics; and there has been discovered the widest of all generalizations in physical science—the law of conservation of energy. Whereas it was easy a century ago to conceive, as in gravitational astronomy, of action at a distance across empty space, the universe in the meantime has come to appear more and more plethoric not only with 'gross matter,' but with that most wonderful entity we call the ether. The astronomers have shown us, in fact, that the number of molar systems in the universe is enormously greater than was supposed possible a century ago; while the physicists have revealed to us molecular systems rivaling our solar system and its Jovian and Saturnian subsystems, and they have loaded down the ether

with a burden of properties and relationships which its usual tenuity seems scarcely fitted to bear. Whereas, also, a century ago the tendency of thought, under the stimulus of the remarkable developments of the elastic solid theory of light and the fluid theories of electricity, was chiefly towards an ether whose continuity would have pleased Anaxagoras, the tendency to-day is chiefly towards an ether whose atomicity would have pleased Democritus.

On the whole, it must be said that the advances of the past century, and especially those of the past half century, have been mainly along the lines of molecular physics. The epoch of Laplace was distinctly an epoch of molar physics; the epoch of to-day is distinctly an epoch of molecular physics. Light, heat, electricity and magnetism have been definitely correlated as molecular and ethereal phenomena; while the recently discovered X-rays and the wonders of radioactivity, along with the 'electrons,' the 'corpuscles' and the 'electrions' of current investigations, all point towards a molecular constitution of the ether. Thermodynamics, likewise, large as it has grown in recent decades, is essentially a development of the molecular theory of gases. It would be too bold, perhaps, to assert that the trend of accumulating knowledge is towards an atomic unity of matter, but the day seems not far distant when there will be room for 'a new Principia' and for a treatise which will accomplish for molecular systems what the 'Mécanique Céleste' accomplished for the solar system.

One of the most important advances of recent decades is found in the fixation of ideas with respect to the units of physical science and in the great improvements which have been wrought in metrology by the 'International Bureau of Weights and Measures.' Our standards of length, mass and time are now fixed with a degree of precision which leaves little to be desired for the present, and the capital resources of measurement and calculation are now available to an extent never hitherto approached.

It should be noted, however, that confidence in the stability of our standards is by no means comparable with the perfection of their current applications. Indeed, we may raise with respect to them the question so long mooted with regard to the motions of the members of the solar system, namely, are they stable? Notwithstanding the admirable precision of the intercomparisons of the prototype meters and prototype kilograms and the equally admirable precision of Professor Michelson's determination of the length of the meter in terms of wave lengths of cadmium light, we can not affirm that these observed relations will hold indefinitely. Our inherited notions of mass have been rather rudely shaken, also, by the penetrating criticisms of Mach, and it appears possible even that the law of conservation of mass may need modification in the light of pending researches. But worst of all, our time unit, the sidereal day, is so far from possessing the element of constancy that we may affirm with practical certainty that it is secularly variable. Having realized, through Professor Michelson's superb determination just referred to, the cosmic standard of length suggested by Maxwell thirty years ago, we are now much more in need of an equally trustworthy cosmic standard of time.

If the progress of physics during the past century has been chiefly in the direction of atomic theory, the progress of chemistry has been still more so. Chemistry is, in fact, the science of atoms and molecules par excellence, a distinction it has maintained for well nigh a full century under the dominance of the fruitful atomic and molecular hypotheses of Dalton and of

Avogadro and Ampère, and under the similarly fruitful laws of gases established by Dalton and Gay-Lussac. Perhaps the most striking feature of this progress, in a general way, is the gradual disappearance it has entailed of the imaginary lines which have been long thought to separate the fields of chemistry and physics. Through the remarkable discoveries of Faraday the two fields have been found to overlap in actual electrical contact. Through the wonderful revelations of spectrum analysis, originating with Bunsen and Kirchhoff, they have been proved to be very largely common ground. And through the broader generalizations inaugurated by Willard Gibbs, Helmholtz and others, they are now both somewhat in danger of being annexed as a subprovince of rational mechanics.

To one whose work has fallen more especially in the fields of precise astronomy, geodesy or metrology, it might seem a just reproach to chemistry that it is a science whose measurements and calculations demand, as a rule, no greater arithmetical resources than those of four-place tables of logarithms and anti-logarithms. The so-called 'Constants of Nature' supplied by chemistry are, in fact, known with a low degree of certainty, a degree expressed, say, by three to five significant figures. A small amount of reflection, however, will convince one that the phenomena with which the chemist has to deal are usually far more complex than those which have yielded the splendid precision of astronomy, geodesy and metrology. Moreover, it should be observed that the certainties even of these highly perfected sciences are very unequal in their different branches. It appears more correct, therefore, as well as more just, considering the central position it occupies and the wide range of its ramifications, along with the vast aggregate of qualitative and quantitative knowledge it has massed, to assert that the precision of chemistry affords the best numerical index of the present state of physical science. That is, when reduced to the most compact form of statement, the certainties of physical science are best indicated, in a general way, by a table of the combining weights of the eighty-odd chemical elements.

When one contemplates the numbers of such a table, and when one adds to its suggestions those which flow from the various periodic groupings of the same numbers, he can hardly avoid being inspired by the day dreams of those who have looked long for the atomic unity of matter. But however the grand problem which thus obtrudes itself may be resolved finally, it appears certain that this table must stand as one of the great landmarks along the path of progress in physical science.

It was justly remarked by Laplace in his 'Système du Monde' that 'L'Astronomie, par la dignité de son objet et par la perfection de ses théories, est le plus beau monument de l'esprit humain, le titre le plus noble de son intelligence'; and we must all admit that subsequent progress has gone far to maintain this high position for the most ancient and interesting of the older sciences. One finds little difficulty in accounting for the early rise of astronomical science and for the universal interest in celestial phenomena. Their immanence and omnipresence appeal even to the dullest intellects. But it is not so easy to account for the remarkable fact that although astronomy deals chiefly with the relations of bodies separated by immense distances, progress in its development has thus far been at least equal to, if not in advance of, the progress of physics and chemistry, which have to deal with matter close at hand. Without attempting a full explanation of this fact, it may suffice to observe that the principal phenomena of astronomy thus far developed appear to be relatively simple in comparison with those of the

other physical sciences; and that the immense distances which separate the celestial bodies, instead of being an obstacle to, are a fortunate circumstance directly in favor of, the triumphant advances which have distinguished astronomical science from the epoch of Galileo down to the present day.

Not less noteworthy than his high estimate of the position of astronomy in his time are Laplace's anticipations of the course of future progress. Our admiration is kindled by the clearness of his vision with respect to ways and means and by the penetration of his predictions of future discoveries. Advances in sidereal astronomy, he rightly thought, would depend chiefly on improvements in telescopes; while advances in dynamical astronomy were to come along with increased precision in the observed places of the members of the solar system and along with the growing perfection of analysis. It is almost needless to say that Laplace's brilliant anticipations have been quite surpassed by the actual developments. Observational astronomy has become one of the most delicately perfect of all the sciences; dynamical astronomy easily outstrips all competitors in the perfection of its theories and in the certainty of its predictions; while the newly developed branch of astrophysics supplies the last link in the chain of evidence of the essential unity of the material universe.

The order of the dimensions and the order of the mass contents of the visible universe, at any rate, have been pretty clearly made out. In addition to the vast aggregate of direct observational evidence collected and recorded during the past century, numerous theoretical researches have gone far, also, to interpret the laws which reign in the apparent chaos of the stars. The solar system, with its magnificent subsystems, has been proved to exhibit the type of stellar systems in general.

In a profound investigation recently published, Lord Kelvin has sought to correlate under the law of gravitation the principal observed data of the visible universe. Assuming this universe to lie within a sphere of radius equal to the distance of a star whose parallax is one thousandth of a second of arc, he concludes that there must be something like a thousand million masses of the magnitude of our sun within that sphere. Light traveling at the rate of 300,000 kilometers per second would require about six thousand years to traverse the diameter of this universe, and while the average distance asunder of the visible stars is considerably less, it is still of the same order. It is only essential, therefore, to imagine our luminary surrounded by a thousand million such suns, most of which are, in all probability, attended by groups of planets, to get some idea of the quantity of matter within visual range of our relatively insignificant terrestrial abode. And the imposing range of the astronomer's time scale is perhaps impressively brought home to us when we reflect that a million years is the smallest convenient unit for recording the life history of a star, while the current events in that history are transmitted across the interstellar medium by vibrations which occur at the rate of about six hundred million million times per second. Measured by its accumulation of achievements, then, the astronomy of to-day fulfils the requirements of a highly developed science. It is characterized by a vast aggregate of accurately determined facts related by theories founded on a small number of hypotheses. In the past it has called forth the two greatest of all systematic treatises, the 'Principia' of Newton and the 'Mécanique Céleste' of Laplace. It has probably done more also than any other science, up to the present time, to illuminate the dark periods during which man has floundered in his struggle for

advancement; and the indications are that its prestige will long continue.

But there are spots on every sun; and lest some may infer, even humorously, as Carlyle did seventy-odd years ago, that our system of the world is 'as good as perfect,' attention should be called to some noteworthy defects in astronomical data and to some singular obscurities in astronomical theory. Here, however, great caution and brevity are essential to avoid poaching on the preserves of our colleagues of the sections. It may suffice, therefore, to merely mention, under the head of defective data, the low precision of the solar parallax, the aberration constant, the masses of the members of the solar system, and the uncertainty of our time unit, already referred to. Two instances, likewise, which belong to the general field of physics as well, may suffice as illustrations of obscurities in astronomical theory. Stated in the order of their apparent complexity, these obscurities refer to the law of gravitation and to the phenomenon of stellar aberration. Probably both are related, and one may hope that any explanation of either will throw light on the other.

So long as no attempt is made to reconcile the law of gravitation with other branches of physics, progress, up to a certain point, is easy; and probably great advantage has resulted from the fact that dynamical astronomers have not been seriously disturbed by a desire to harmonize this law with the more elementary laws of mechanics. Perhaps they have unconsciously rested on the platform that gravitation is one of the 'primordial causes' which are impenetrable to us. There are some indications that even Laplace and Fourier did so rest. But, however this may be, it has grown steadily more and more imperative during the past century to explain gravitation, or to discover the mechanism which provides that the force between two widely separated masses is proportional to their product directly and to the square of the distance between them inversely. All evidence seems to indicate that the ether must provide this mechanism; but, strangely enough, so far, the ether has baffled all attempts to reveal the secret. The problem has been attacked also on the purely observational side of the numerical value of the gravitation constant. But the splendid experimental researches for this purpose throw no light on the mechanism in question, and, unfortunately, they bring out values for the constant of a low order of precision.

With regard to stellar aberration, it must be at once admitted that we have neither an adequate theory nor a precisely determined fact. The astronomer has generally contented himself with the elementary view that aberration is a purely kinematical phenomenon; that the earth not only slips through the ether without sensible retardation, but that the ether slips through the earth without sensible effects. This difficulty was recognized, in a way, by Young and Fresnel, and, although the subject of elaborate investigation in recent decades, it has proved equally baffling with Newtonian gravitation. As in the case of the latter also, the numerous attempts made to determine the constant of aberration by observational methods have been rewarded by results of only meager precision. Possibly the time has arrived when one may raise the question, Within what limits is it proper to speak of a gravitation constant or of an aberration constant?

If we agree with Laplace that astronomy is entitled to the highest rank among the physical sciences, we can accord nothing short of second place to the sciences of the earth. Most of them are, indeed, intimately related to astronomy; and some of them are scarcely less ancient in their origins, less dignified in their objects, or

less perfect in their theories. Primarily, also, it should be observed, geophysics is not simply a part of, but is the very foundation of, astronomy; for the earth furnishes the orientation, the base-line, and the timepiece by means of which the astronomer explores the heavens. Geology, likewise, in the broader sense of the term, as we are now coming to see, is a fundamental science not only by reason of its interpretations of terrestrial phenomena, but also by reason of its parallel interpretations of celestial phenomena; for there is little doubt that in the evolution of the earth we may read a history which is in large degree typical of the history of celestial bodies. In any revised estimate, therefore, of the relative rank of the physical sciences, while it would be impossible to lower the science of the heavens, it would appear essential to raise the sciences of the earth to a much higher plane of importance than was thought appropriate by our predecessors of a hundred years ago.

As with physics, chemistry and astronomy, the wonderful progress of the nineteenth century in geophysical science has been along lines converging towards the more recondite properties of matter. All parts of the earth, through observation, experiment, induction and deduction, have yielded increasing evidence of limited unities amid endless diversities. Adopting the convenient terminology of geologists for the different shells of the earth, let us glance rapidly in turn at the sciences of the atmosphere, the hydrosphere or oceans, the lithosphere or crust, and the centrosphere or nucleus.

The atmosphere is the special province of meteorologists, and although they are not yet able to issue long-range predictions, like those guaranteed by our theories of tides and terrestrial magnetism, it must be admitted that they have made great progress towards a rational description of the apparently erratic phenomena of the weather. One of the peculiar anomalies of this science illustrates in a striking way the general need of additional knowledge of the properties of matter; in this case, especially, the properties of gases. It is the fact that in meteorology greater progress has been made, up to date, in the interpretation of the kinetic than in the interpretation of the static phenomena of the atmosphere. Considering that static properties are usually much simpler than kinetic properties, it seems strange that we should know much more about cyclones, for example, than we do about the mass and the mass distribution of the atmosphere. In respect to this apparently simple question meteorology seems to have made no advance beyond the work of Laplace. There are indications, however, that this, along with many other questions, must await the advent of 'a new Principia.'

The geodesists, who are the closest allies of the astronomers, may be said to preside over the hydrosphere, since most of their theories as well as most of their observations are referred to the sea level. They have determined the shape and the size of the earth to a surprising degree of certainty; but they are now confronted by problems which depend chiefly on the mass and mass distribution of the earth. The exquisite refinement of their observational methods has brought to light a minute wandering in the earth of its axis of rotation, which makes the latitude of any place a variable quantity; but the interpretation of this phenomenon is again a physical and not a mensurational problem. They have worked improvements also in all kinds of apparatus for refined measurements, as of base-lines, angles and differences of level; but here, likewise, they appear to approach limits set by the properties of matter.

The lithosphere was once thought to be

the restricted province of geologists, but they now lay claim to the entire earth, from the center of the centrosphere to the limits of the atmosphere, and they threaten to invade the region of the astronomers on their way towards the outlying domain of cosmogony. Geology illustrates better than any other science, probably, the wide ramifications and the close interrelations of physical phenomena. There is scarcely a process, a product or a principle in the whole range of physical science, from physics and chemistry up to astronomy and astrophysics, which is not fully illustrated in its uniqueness or in its diversity by actual operations still in progress on the earth, or by actual records preserved in her crust. The earth is thus at once the grandest of laboratories and the grandest of museums available to man.

Any summary statement, from a non-professional student, of the advances in geology during the past century, would be hopelessly inadequate. Such a task could be fitly undertaken only by an expert, or by a corps of them. But out of the impressive array of achievements of this science, two seem to be specially worthy of general attention. They are the essential determination of the properties and the rôle of the lithosphere, and the essential determination of the time scale suitable for measuring the historical succession of terrestrial events. The lithosphere is the theatre of the principal activities, mechanical and biological, of our planet; and a million years is the smallest convenient unit for recording the march of those activities. When one considers the intellectual as well as the physical obstacles which had to be surmounted, and when one recalls the bitter controversies between the Neptunists and the Vulcanists and between the Catastrophists and the Uniformitarians, these achievements are seen to be amongst the most important in the annals of science.

The centrosphere is the *terra incognita* whose boundaries only are accessible to physical science. It is that part of the earth concerning which astronomers, geologists and physicists have written much, but concerning which, alas! we are still in doubt. Where direct observation is unattainable, speculation is generally easy, but the exclusion of inappropriate hypotheses is, in such cases, generally difficult. Nevertheless, it may be affirmed that the range of possibilities for the state of the centrosphere has been sharply restricted during the past half century. Whatever may have been the origin of our planet, whether it has evolved from nebular condensation or from meteoric accretion; and whatever may be the distribution of temperature within the earth's mass as a whole; it appears certain that pressure is the dominant factor within the nucleus. Pressure from above, supplied in hydrostatic measure by the plastic lithosphere, supplemented by internal pressure below, must determine, it would seem, within narrow limits the actual distribution of density throughout the centrosphere, regardless of its material composition, of its effective rigidity or of its potential liquidity. Here, however, we are extending the known properties of matter quite beyond the bounds of experience, or of present possible experiment; and we are again reminded of the unity of our needs by the diversity of our difficulties.

In his recently published autobiography, Herbert Spencer asserts that at the time of issue of his work on biology (1864) 'not one person in ten or more knew the meaning of the word * * *; and among those who knew it, few cared to know anything about the subject.' That the attitude of the educated public towards biological science could have been thus indifferent, if

not inimical, forty years ago, seems strange enough now even to those of us who have witnessed in part the scientific progress subsequent to that epoch. But this was a memorable epoch, marked by the advent of the great intellectual awakening ushered in by the generalizations of Darwin, Wallace, Spencer and their coadjutors. And the quarter of a century which immediately followed this epoch appears, as we look back upon it, like an heroic age of scientific achievement. It was an age during which some men of science, and more men not of science, lost their heads temporarily, if not permanently; but it was also an age during which most men of science, and thinking people in general, moved forward at a rate quite without precedent in the history of human advancement. A new, and a greatly enlarged, view of the universe was introduced in the doctrine of evolution, advanced and opposed alike, vigorously, chiefly by reason of its biological applications and implications. Galileo, Newton and Laplace had given us a system of the inorganic world; Darwin, Spencer and their followers have foreshadowed a system which includes the organic world as well.

The astonishing progress of biology in recent times furnishes the most convincing evidence of the unity and the efficiency of the methods of physical science in the interpretation of natural phenomena. For the biologist has followed the same methods, with changes appropriate to his subject-matter, only, as those found fruitful in astronomy, chemistry and all the rest. And whatever may be the increased complexity of the organic over the inorganic world, or however high the factor of life may seem to raise the problems of biology above the plane of the other physical sciences, there has appeared no sufficient reason, as yet, to doubt either the validity or the adequacy of those methods.

Moreover, the interrelations of biology with chemistry and physics especially, are yearly growing more and more extended and intimate through the rapidly expanding researches of bacteriology, physiology and physiological chemistry, plant and animal pathology, and so on, up through cytology to the embryology of the higher forms of life. Through the problems of these researches also we are again brought face to face, sooner or later, with the problems of molecular science.

And finally, what may be said of anthropology, which is at once the most interesting and the most novel of the physical sciences, interesting by reason of its subject matter, novel by reason of its applications? Some of us, perhaps, might be inclined to demur from a classification which makes man, along with matter, a fit object of investigation in physical science. Granted even that he is usually a not altogether efficient thermodynamic engine, it may yet appear that he is worthy of a separate category. Fortunately, however, it is not a rule of physical science to demand immediate answers to such ulterior questions. It is enough for the present to know that man furnishes no exception, save in point of complexity, to the manifestations of physical phenomena so widely exhibited in the animal kingdom.

But whatever may be our inherited prejudices, or our philosophic judgments, we are confronted by the fact that the study of man in all his attributes is now an established domain of science. And herein we rise to a table-land of transcendent fascination; for, to adapt a phrase of an eminent master in physical science, the instruments of investigation are the objects of research. Herein also we find the culminating unity, not only of the physical sciences, but of all of the sciences; and it is chiefly for the promotion of these higher interests of anthropology that we are as-

sembled in this cosmopolitan congress to-day.

It has been our good fortune to witness in recent decades an unparalleled series of achievements in the fields of physical science. All of them, from anthropology and astronomy up to zoology, have yielded rich harvests of results; and one is prone to raise the question whether a like degree of progress may be expected to prevail during the century on which we have now entered. No man can tell what a day may bring forth; much less may one forecast the progress of a decade or a century. But, judging from the long experience of the past, there are few reasons to doubt and many reasons to expect that the future has still greater achievements available. It would appear that we have found the right methods of investigation. Philosophically considered, the remarkable advances of the past afford little cause for marvel. On the contrary, they are just such results as we should anticipate from persistent pursuit of scientific investigation. Conscious of the adequacy of his methods, therefore, the devotee to physical science has every inducement to continue his labors with unflagging zeal and confident optimism.

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*MICRO-ORGANISMS OF SOIL AND HUMAN WELFARE.**

Man has gained dominion in the earth not as a birthright, but by many struggles and by numerous conquests. Slowly during the ages he has gained accessions of knowledge and has succeeded in making more and more use of the forces of nature. The introduction of the art of printing enabled him to make readily and to keep permanently a record of his accomplishments; the discovery of the mariner's compass added immensely to his domain; the application of steam multipled a thousand times his power, and now the subjection of the electric forces makes him a veritable master over time and space. As a help in gaining knowledge applicable to the practical affairs of earth and life the microscope stands unrivaled. Its relations have been incomparably important in regard to the knowledge of man himself and to those things immediately connected with his daily existence and health. Bacteriology is a branch of microscopy or at all events could not have been developed without the aid of the microscope, and in this connection alone the instrument has been useful beyond any other piece of mechanism whatever in alleviating ills to which flesh is heir and in promoting and prolonging life.

So far bacteria have been more especially studied as disease germs. Witness the advance which has been made on account of those studies in medicine and surgery, in the efficiency of quarantines and in the prevention of epidemics. It is argued now in some quarters that even old age is a germ disease, and that immortality on earth is a possibility when bacteriology and its allied sciences come to perfection. I am to ask your attention at this time to some of the microorganisms of the soil and their relation to soil fertility. This is a technical subject. While it is not possible to treat it as a popular theme, it should not be difficult to show that there are matters here which, whether we are aware of it or not, intimately and immeasurably affect every human being on earth.

First a few words as to the organisms themselves. They are minute living creatures belonging to the vegetable kingdom, hence called plants, however unlike they are to the leafy structures usually alluded to by that name. Their most striking peculiarities are their exceedingly diminutive

* Presidential address read at the Buffalo meeting, August 24, 1904, of the American Microscopical Society.

size, and their possibilities of reproduction. In the terms of the microscopist a half micron is about the diameter of the smaller kinds and twice this for the larger ones. That is, from .0005 to .001 mm., or .00002 to .00004 inch. It requires 13 sheets of the typewriting paper on which this is written to measure in thickness one mm., therefore there is room across the cut edge of one sheet for about 77 of the larger or 144 of the smaller of these bacteria to lie side by side. Of course a single organism is absolutely invisible to the naked eye and can not be seen without more than 100 times magnification. To study bacteria effectively the best compound microscope is often taxed to its utmost limits.

Over and against the diminutive size may be placed the extraordinary powers of multiplication of these minute creatures. In the case of many common species any one of the organisms may become two by a simple process of self-division within thirty minutes of time, when conditions are favorable. At this rate at similar intervals of a half hour each, two become four, four become eight, eight become sixteen, etc. This continued for 48 half-hours, one day and night, makes the enormous number of 281,470,000,000 individuals. This seems incredible, but a little calculation which can be made by any schoolboy will prove the statement. As shown by the census of 1900, there were then in Illinois 4,881,450 people. The number of bacteria produced in 24 hours from a single organism is, according to this, 58,327 times as many as the human population of Illinois, and is equal to something like 185 times the number of people in the whole world.

We are not to take from this that such a rate of multiplication ever actually continues for any very considerable time, for, small as these single organisms are, there would soon be room for nothing else on the earth. This rate of growth and self-division only occurs while all the conditions are favorable. Now, even if other things so continued, the prodigiously increasing numbers themselves would soon interfere with further advance. There are limitations here as there are to the number of people in a house. Even if nothing else prevents, their own excretions or other products may arrest growth. For instance, the souring of milk is for the most part caused by a particular species of bacteria. The individual organisms belonging to this species increase very rapidly in fresh milk at the proper temperature, and lactic acid is produced. But the proportion of this acid does not rise above eight tenths of one per cent., for this amount becomes prohibitive of further activity on the part of the organism. Its numbers do not further increase unless the acid is more or less neutralized by some alkaline substance. From some such cause our phenomenal numbers are not often found as the product of one bacterium in 24 hours, but the calculations do show approximate facts and do help us to explain observed results. One bacterium, perhaps one thirty-thousandth of an inch in diameter, far too small to be seen by the unaided eye, can do comparatively nothing while several thousands of them in a drop of broth may soon cause its putrefaction.

So much has been said of bacteria as germs of virulent diseases, as agents of pollution, as destroyers generally that we may well think of them as invisible enemies with which we must ever battle to live, or to have anything to live upon. To-day we are to discuss some of the benefits they confer upon us, and we shall see that not all good bacteria are dead bacteria. If they, or some of them, are destroyers and enemies to be feared, they, or some of them,

are also helpers and colaborers to be favored.

The total number of bacteria in any soil capable of sustaining luxuriant vegetation is always very great and they vary in somewhat close proportion to the degree of fertility. In the first foot of rich garden earth about one to five millions per cubic centimeter commonly exist, though many times the larger number may be present when there is much decomposable matter and the conditions are favorable for rapid multiplication. The numbers rapidly decrease in the deeper layers, so that at three feet comparatively few are usually found, and at two or three times this depth they are practically absent. The numbers of all kinds have, however, less meaning than has the presence and activity of certain specific kinds—those which have to do with the original formation of soil and some active and efficient helpers in the maintenance of soil fertility.

ROCK REDUCERS. NITRIFIERS.

We all understand that what we term soil is not simply the crust of the earth in its original condition. The old-time rocks through long eons of time, by various agencies, have been crushed and comminuted, and the more or less pulverized materials have been mixed, transported and deposited by titanic forces and upon a scale of gigantic proportions. Mechanical agencies have been operative in the stupendous changes which have taken place in the reduction of the original rocks to the forms of sand and clays in strata as we find them, but only in recent times has it become known that certain microscopic living beings have had a share in the process. In spite of their diminutive size and of their low organization, in spite of their invisibility and of their individual nothingness, they are helpers in the accomplishment. It is customary to speak of the crumbling of exposed surfaces of rocks as due to the weather, and the process is called weathering. But in these later days it has been found that this change is largely due to living organisms, just as the decay of fruits and the putrefaction of the flesh of animals, formerly supposed to be brought about by mere exposure to the air, are now well known bacterial operations. We know now that the process of canning fruits and meats succeeds not by keeping out the air as we formerly thought, but by keeping out bacteria. In the so-called weathering of rocks and the formation from them of soil, it is not so much the air, the rain, the frost, etc., which perform the work as it is our minute friends the bacteria.

Until recently it was supposed to be impossible that any bacteria could live without organic food supplies. It is and has been well known that green vegetation builds up organic matter from inorganic compounds under the energizing agency of sunshine. For instance, starch is formed in green leaves from carbon dioxide and water—the former absorbed from the air and the latter taken up by the roots; and there is no other way known to man by which starch is formed from elementary materials. A very large proportion of our food and that of all animals consists of starchy products so primarily produced, hence the operation is an immensely important one and all due to green leaves. They are almost miracle workers, but it had not been imagined that colorless bacteria could in any measure share with these higher forms of plant life as miracle-working agencies in this respect. Yet these bacteria that live on bare rocks get their sustenance from these and from the air, and in their life processes actually store up organic matter. That is, they are soil makers, fertility producers, advance agents

in the making of a farm. They absorb and utilize the carbon dioxide of the air and when they die the carbonaceous compounds so formed are in part left as a component of what we call the humus element of soil. These bacteria are thus actively engaged in reducing the mineral substances to a pulverized form and as actively helping to provide a store of organic matter towards the formation of soil suitable for higher plants. It is remarkable, too, that these organisms are capable of accomplishing this work in the dark. As they do not derive their energy from light, as is the case with green plants, they must utilize some other radiant force or form of force for this purpose, possibly heat rays, or others not so well understood; or it is suggested that they derive their energy directly from the oxidizing processes they set up. At all events, they are wonder-working little creatures.

But our story concerning these particular kinds is not all told. Most micro-organisms acting upon nitrogenous matters are destroyers of these compounds in such sense that the substances are rendered less available as food for higher plants. They are *denitrifying* agents. These peculiar species do just the reverse. They put nitrogenous compounds which are little or not at all utilized by higher vegetation in available shape and so contribute to soil fertility in another way. They can absorb ammoniacal gas washed by rains from the atmosphere or they can act upon insoluble salts of ammonia existing in the soil and form nitrites first, and then nitrates, in which latter condition common plants can use them. This is called *nitrification,* and the bacteria nitrifying agents. There are two groups of these workers. One set of species oxidize ammonia or its compounds to nitrites and another set further change these nitrites to nitrates. A very curious thing is that these bacteria are not able to exert their activities in the presence of soluble organic matter—the very condition most favorable for most other micro-organisms. Even ammonia in a free state is an antiseptic to the nitrate formers. Soil that is liberally supplied with actively decomposing organic matter may have an abundance of these latter bacteria, but they are practically inactive until the decomposition has passed certain stages of its process. In the meantime this soil may be poorly suited for crops until later when the nitrifying processes are resumed. Denitrification can go on in a compact soil, but nitrification requires air. It seems that the stimulating effect of tillage is very considerably due to nitrifying activity, so induced; that is, we cultivate soil in part to favor these peculiar bacteriological friends. We see too how tile drainage may indirectly improve the productive capacity of the soil by securing better penetration of air and so again aid our friends, the nitrifiers. Again, these latter can not work in an acid medium. Sometimes the application of lime to certain soils proves to be greatly advantageous, not perhaps because there is too little of this substance for plant food, but because it corrects the acidity and permits, among other things, the nitrifying bacteria to work. Possibly in the full development of agricultural science there will be found more direct methods of securing the voluntary services, to their highest efficiency, of these minute friends of man.

It should be said that these nitrifying bacteria appear to be always present in all soils in sufficient numbers, hence there is little reason to suppose that anything can be gained by the addition of artificial cultures or of impregnated earth—processes which may be decidedly helpful in the case of certain other bacteria to be spoken of later—but it seems evident enough that

methods of soil management have much to do in favoring or hindering the activities of these helpful little creatures. Some day farmers will come to understand that specialists working in laboratories and who for long hours gaze through the microscope are gradually gaining knowledge of fundamental importance to them.

ROOT-TUBERCLE BACTERIA.

As has been said, there are astonishing numbers of bacteria in all fertile soils, often attaining many millions in a little cube one centimeter (two fifth inch) in diameter, and numerous different kinds have been identified. Each of these kinds has certain special activities as well as peculiar structural characteristics. Most of them are concerned in the decomposition of organic matter and in this sense are destroyers, though we must not by any means call them enemies. If they do cause the fermentation or putrefaction of organic substances, these very operations are widely advantageous, since by this means useless materials are put out of the way or, perhaps, are converted into forms of utility. In this way the humus ingredient of fertile soils is mainly supplied.

But most of these innumerable organisms do not add anything to the soils, they simply change the state or condition of matters previously present. This is true of the nitrifying kinds mentioned above except that they do absorb the carbon dioxide of the air and contribute carbon to the soil in the solid form—a slim advantage, however, in the case of soils already formed, since green-leaved plants accomplish this on a much larger scale. The nitrifying bacteria are decidedly useful little creatures because of the desirable changes they bring to pass in organic materials present in the soil, not because of any contributions from an outside source through their agency.

There are, however, other peculiar bacteria not everywhere present among the hosts of living organisms commonly at home in fertile soils which do aid in such additions. If they are peculiar in distribution they are apparently more peculiar in their mode of action and in the results produced. After much careful investigation and no little difference of opinion it has been conclusively settled that green vegetation can not make direct use of the free nitrogen of the air, though combined nitrogen, mostly in the form of nitrates, is absolutely essential to their life and growth. These nitrates are freely soluble in water and tend to leach away. If, therefore, we should return to the soil everything that grows upon it, we should still find fertility decreasing, unless in some way nitrogen could be added from an extraneous source. The store of this substance is not inexhaustible in any soil. In spite of any contributions which could be made from the products of the soil itself, whether these were first fed to animals or not, this essential element of fertility would considerably and constantly diminish. A small amount of ammonia, the product of fermenting matters or of electric combinations, is washed from the air by rain, but too little seriously to affect the problem of the maintenance of soil fertility.

Now we know that soils in nature have not deteriorated. Without help from man they have, through thousands of years, gained instead of lost their nitrogenous supplies; though it must be true that great losses have in the meantime occurred by drainage. There must, therefore, be some means of supply, some accession from without which more than balances the losses. If green vegetation can not absorb and combine the free nitrogen of the air, of which the quantity is practically unlimited, something else must do so.

During the twenty-five years from 1866 to 1891 observations and experiments by several investigators upon peculiar swellings on the roots, especially of leguminous or pod-bearing plants, resulted in showing that these are inhabited by bacteria, and that the green plants having them do in some way gain their needed nitrogen from the air when it is not available from the soil. This was a great discovery. It had long been known that these plants rendered soil more fertile for other crops afterward grown on the same land, and rotations had long been practised with clover as one of the crops for its fertilizing effects. How the clover acted as a fertilizer was not known until about fifteen years ago. Since that time our knowledge upon the subject has very considerably increased and every year now something more is learned.

The facts seem to be in general somewhat as follows: leguminous plants unaided have no more ability to help themselves to the nitrogen of the air under any circumstances than have other green plants. Certain bacteria existing in the soil penetrate the soft tissues of young roots of legumes and multiply within these living tissues so as to form a little mass of gelatinous substance. Responding to the irritation produced, the plant builds a nodular structure about the bacterial invaders, not unlike the formation of a gall consequent upon the sting of an insect. Numerous nodules may be formed on the roots of one plant and they have characteristics peculiar to the species of plant on which they occur. Some are characteristically much larger than others, varying from the size of the smallest seeds to more than that of garden peas, or they grow in different shapes, or have different forms of grouping, etc. In some way not well understood these plants with nodules or tubercles are capable of getting sufficient nitrogen from the air abundantly to serve their purposes when the soil has no supplies, and when other plants must die from the want of it. Either the bacteria are direct agents in the process or they aid the plant itself to do what without such aid it can not do.

The number of bacteria in one of these root tubercles is very large, altogether countless, yet the total number thus dwelling within the roots is insignificant when compared with the number in the soil outside. But these in the root are specifically different from those, and seem to have a decidedly different office to fulfil. As was said above, they are not common soil bacteria. They may, and sometimes do, live even some years in the soil outside of living roots, but they never become numerous among the other kinds and are often entirely wanting, however rich the soil may be otherwise.

There is a disputed question whether these root-dwelling bacteria all belong to one species with some temporary variation into races each adapted to a special kind of leguminous plant, or whether there are numerous species, almost as many as there are genera of legumes, upon which they are found. This may be thought to be an unprofitable inquiry, but it may mean more than we see at first glance. There is no longer any question but that there is some kind of difference among them. Those that form tubercles on the roots of clover fail entirely to develop on garden peas and on soy beans, and those that accompany soy beans appear to have no effect upon alfalfa. Some of them grow differently in artificial cultures and appear to have, under the microscope, various different characteristics. In certain instances it has been shown, however, that kinds usually associated with certain legumes can become adapted to others which they did not previously accompany, and this has been held

to mean that in all cases the recognized form and functional differences are temporary modifications and that all are one natural species. There is really a very important matter here which we trust we shall soon know more about. If those which normally inhabit one species of leguminous plants can be modified by artificial cultures so as to grow upon another species of legumes, may further modifications be induced so that growth may take place upon some plant not a legume? There is no known reason why legumes particularly are hosts of these organisms to the exclusion of other kinds of vegetation. As a matter of fact, there are other and very different kinds of plants upon which similar root tubercles are found, namely, shrubs or trees of the genus *Alnus* or alder (not elder); two or three species of the family Eleagnaceæ, European shrubs sometimes cultivated with us for their silvery foliage; and—what appears more strange—upon coniferous trees of the southern hemisphere belonging to the genus *Podocarpus*. It has now become well known that the root tubercle organisms peculiar to alfalfa are not very widely distributed in our country and that in many cases the former can not be profitably raised without artificial inoculation of the soil. In such cases a remedy is found in scattering earth taken from a field where the plant has been successfully grown and where the nodules on the roots have been observed. A similar statement may be made with reference to soy beans, and there are areas, though not so common, where the bacteria which form tubercles on the roots of clover do not exist. In such areas the clover plant no more contributes to soil fertility than do other kinds of green vegetation.

We have asked: Can these legume organisms or some of them be made to form tubercles on other plants, for instance, upon maize? Here is a matter of the greatest moment. Undoubtedly they have some time in the past become adapted to leguminous vegetation. There is nothing to prevent the supposition that they may possibly be made to adjust themselves to corn. If so, what a triumph this would be for scientific experimentation. What an advance it would mark for scientific agriculture. We know that corn can be very decidedly modified in its chemical composition by processes of breeding. Types of grain can be produced in which, for instance, the nitrogenous percentage is greatly increased, and so a long way improved as food for man and beast. If, in addition to this, Indian corn can be made to furnish itself, through accommodating bacteria, with this higher nitrogen content directly from the exhaustless storehouse of the air, the agricultural miracle of the age will have been wrought. No one can predict whether or not this will ever come to pass. But from what is now known the endeavor to bring it to pass seems at least worth while.

Some years ago there were put up in certain German laboratories substances under the name of *nitragin* which were supposed to be pure cultures of living bacteria severally suitable for different leguminous crops, and it was thought that great results would follow the proper application of these cultures to fields seeded with the various legumes. Patents were taken out in Europe and in this country protecting the manufacture and use of these substances, but little seems to have come of the matter. Now the Department of Agriculture at Washington is sending out what are supposed to be improved cultures for a similar purpose, and some very favorable reports of their use have been made. It is too soon to determine how valuable the results are

to be. Surely tests are abundantly worth trying.

NITROGEN FIXATION BY FREE BACTERIA.

It was asserted above that little is known of the method by which leguminous plants in connection with root-tubercle bacteria accumulate nitrogen. It remains to be said that some experiments have shown that these same bacteria in artificial cultures can of themselves absorb and combine aërial nitrogen; that is, the legume bacteria are nitrogen fixers without any aid from leguminous plants. There is no proof, however, that this is done in nature, that these organisms, while in the soil outside of the root tissues, appropriate free nitrogen and build it into compounds which become suitable for plant food. It is, however, known that some other bacteria, not tubercle formers, do accomplish this task, for in unsterilized soils free from green vegetation an increase in the nitrogen content is found to take place under circumstances which preclude the accession except from the free nitrogen of the air; while in sterilized soils of the same kind under the same conditions no increase occurs. Since there is nothing else but bacteria in the unsterilized soil to which the phenomenon can be attributed, search has been carefully made for the active agents. After many tests upon numerous soil-inhabiting species, certain kinds of bacteria have been found which undoubtedly have the power of building the aërial nitrogen into combinations which subsequently serve as food for higher plants. In this case we must understand that the process is accomplished solely by the bacteria, and it is by different species from those forming root tubercles. In fact, several different kinds of bacteria and some molds are now known which thus contribute to soil fertility, but in most cases the quantity of nitrogen fixed is very small.

Two species, however, have been discovered which are apparently very efficient in the process, viz., *Clostridium Pasteurianum* Parzm. and *Bacillus Ellenbachiensis* Stutzer-Hartleb, and an artificially prepared substance called *alinit* has been placed on sale in Germany which appears to be a pure culture of the latter. Practical tests with alinit have not upon the whole shown that its application to soils results in any considerable increase in crops, though in some instances favorable reports have been made. The discovery that the organism has under some conditions the effect of reducing nitrates to nitrites makes it seem less certain that the commercial preparation will prove valuable.

Here we pause. Our story has been a long one, yet only a meager account has been given of some of those soil bacteria which are efficient agents in preparing for, or furnishing, higher vegetation an essential constituent of their food. We have seen that in the most sterile soils certain nitrifying organisms are constantly at work utilizing ammonia washed from the atmosphere by rains or converting ammonia salts into nitrites, which are in turn oxidized by other species of bacteria into nitrates, the form suitable for the sustenance of higher vegetation. Again, the root-tubercle bacteria make a way for leguminous plants to use the free nitrogen of the air and to build up in their own structures compounds which contribute essentially to the fertility of the land when these structures decay. And then certain other soil bacteria are direct agents in the binding of free nitrogen into complex combinations within their own bodies, which upon their death are fitted by the agency of other bacteria to combine with the mineral constituents of the soil, to the effect that fertility is increased, even where the apparently bare earth seems lying idle, wasting in the sun.

While these particular operations are in progress countless hoards of bacteria of various kinds are each exercising their natural functions in the rôle of destroyers or helpers, as the case may be. Surely we may think of the soil as a factory full of busy workers, causing incessant changes and modifications, rather than as a simple storehouse of accumulated riches.

The prosperity of peoples depends upon other factors than the fertility of the soil on which their homes are made, but those countries which are naturally most fertile furnish man more easily and more abundantly those things which may be used by him in increasing his power and in promoting his highest interests. In Illinois the local passenger traffic on the railroads is found to vary conspicuously with the difference over large areas in the quality of the soil, though all of the country is well populated. Not only is the number of the passengers in the regions of the best soils several times greater, but the difference in character of the men and women is also evident. The towns in the one case have great business houses, elegant residences, paved streets, electric railroads and lights, fine churches and school-houses, and a progressive, strong, hopeful and happy populace; while in the other these things are noticeably wanting, except in some measure the numbers of people. These take unconsciously a slower step, require more time in which to transact business and have less relish for physical or mental activity. They are evidently not so well fed and are in consequence really less capable of sustained exertion. Then, too, there is a stimulus in success itself which animates and inspires, while hopefulness is half the battle. Repeated failure of crops not only discourages the husbandman, but robs the entire community of life and push, and this is as true of mental and moral as of physical activities. Soil fertility and man's virility are closely related. Therefore, since certain bacteria have been proved to have direct and very important connection with the former, they have in like measure evident and decided bearing upon the latter. If all flesh is grass, all nutrition as applied to man seems to be ultimately conditioned upon the activity of certain micro-organisms of the soil.

Man has proved himself to be a mighty master. Formerly the storm-tossed oceans toyed like bubbles with his contrivances and the great billows were barriers to navigation. Now the tempestuous waters are luxuriant pathways of travel, and down in their silent depths they pulsate from shore to shore with vibrant intelligence. Continents are spanned with iron and the massive locomotives thunder over the rivers and plunge under the mountains, defiant of opposition but delicately responsive to human control. How man has swept the forests from the face of the globe, and made at his will the wilderness to blossom as the rose! The earth, the air, the waters have yielded to him their secrets and the forces thereof have become the obedient servants of his commands. But master as he is, potent as is his sway, he never could have gained a livelihood, nor could he now long maintain existence on the earth, without the aid of myriads of invisible, though organized and living, silent though industrious and efficient agents of the microscopic world. It becomes him, therefore, to seek acquaintance with these beneficent creatures and to find ways and means of favoring their life-giving activities.

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SCIENTIFIC BOOKS.

The Classification of Flowering Plants. By Alfred Barton Rendle, M.A., D.Sc., F.L.S., assistant in the department of botany, Brit-

ish Museum, and lecturer in botany at the Birkbeck College. Vol. I., Gymnosperms and Monocotyledons. Cambridge, at the University Press. 1904. Pp. xiv + 403. 8vo. 187 figures in the text.

The purpose of this book is stated by the author to be 'an attempt to give the student who has some acquaintance with the rudiments of botany a systematic account of the flowering plants.' By 'flowering plants' Dr. Rendle here means the seed plants, so that the pines, cedars, yews and their relatives are included under the term. That the author does not himself agree with this grouping is clearly shown in the preface, where he goes so far even as to doubt the paramount value of the seed character in classification. However, after expressing this doubt, he concludes 'on the present occasion' to treat the gymnosperms (pines, cedars, yews, etc.) and angiosperms (lilies, grasses, buttercups, pinks, mints, roses, parsleys and sunflowers) as parts of a single great group.

The first chapter, of about thirty pages, is given to a short historical statement of the development of plant classification. While brief, this is a useful summary, especially for those not having access to considerable libraries. The treatment is quite unequal. Thus a half page each is allotted to Robert Brown and John Lindley, and but a page to Endlicher, while to Van Tieghem and his singular systems are given more than five and a half pages. The system adopted by the author is essentially that of Engler in the third edition of his 'Syllabus der Pflanzenfamilien.'

The book is logically arranged, beginning with those groups which the author considers to be lower and primitive. Thus we have taken up first a discussion of the structure of the reproductive and vegetative organs of the Cordaitales, extinct since the Carboniferous period. Naturally the treatment is brief and incomplete for want of good material, but it must be said that the author has made the most of the little that we know of these primitive gymnosperms. Then follows a longer chapter on the Cycadales, in which the author confines his discussion wholly to the living forms. Next comes a short chapter on Bennettitales, extinct since the Mesozoic period, followed by one on Ginkgoales, based mainly upon the single living, *Ginkgo biloba,* but with some reference to extinct species. In passing it may be noted that Dr. Rendle considers the structures on which the ovules of *Ginkgo* are borne to be axial. We much prefer Van Tieghem's interpretation of these structures as foliar in nature. The chapter on the Coniferales is by far the longest, as it should be. The usual morphological views are adopted, and the grouping of the genera is quite like that with which we are familiar. In regard to the nature of the seed-scale of the pines and their allies, the views of many investigators are given, and the whole is summed up by the statement that 'the view that the scale and ovule represent a secondary axis arising in the axis of the bract is at present the most generally accepted one.' In the treatment of Gnetales there is nothing new. The acceptance of the name *Tumboa* (instead of *Welwitschia*) is significant. A few years ago such an application of the 'law of priority' would have been most unlikely.

In taking up the angiosperms about fifty pages are given to a chapter devoted to their general morphology, in which we have considerable injection of modern morphology and terminology into what is for the most part a treatment along old lines. In reading the pages of this chapter one is impressed with the feeling that the author is condensing and abbreviating his discussion, with a consequent loss of clearness. For the student who has no more than 'some acquaintance with the rudiments of botany' many of the statements of the author will not be understood, and will have to be supplemented by much elucidation at the hands of his instructor.

The chapter dealing with the monocotyledons is well worked out, about two hundred pages being given to their morphology and classification. Following Engler's system the Pandanales are taken up first, with the remark that in them 'the flower is extremely indefinite' and that 'we have here presumably a primitive condition, prior to the evolution of the more typical arrangement.' The Helobieæ follow with the usual treatment, in-

cluding the Hydocharideæ. Under the Glumifloræ the grasses (Gramineæ) are described as having a solitary carpel, which is certainly an error for the three-styled genera, and probably so for those with two styles. Hackel's arrangement is followed. Curiously, in the sedges (Cyperaceæ) the carpels are described as 'three or two.' How these two views as to the nature of the pistil can be harmonized is difficult to make out.

The palms and aroids (Principes and Spathifloræ of Engler) are united into the 'series' Spadicifloræ. A curious typographical error occurs on page 250 (and is repeated on page 256) where the number of species of palms is given as 11,000! The treatment of the remaining groups (Farinosæ, Liliifloræ, Scitamineæ and Microspermæ) is in all essentials in accordance with that in Engler's 'Syllabus.'

The final chapter is devoted to a general review and to suggestions of affinities between the groups. This has not been well wrought out, and the student will be much confused by some of the statements. For example, while we are told that 'the Glumifloræ represent a primitive type,' and 'we may regard them as the stock from which the higher series have been derived,' we are told over and over again that the grasses are highly specialized. The diagram at the close of the chapter, while helpful in enabling us to understand the author's position, will scarcely help the student to an understanding of nature. According to it there are three monocotyledonous phyla, viz., (1) Helobieæ, (2) Pandanales, Spadicifloræ, (3) Glumifloræ, Farinosæ, Liliifloræ, Scitamineæ, Microspermæ.

Throughout the book, 'order' of Engler is given as 'series,' and 'family' as 'order,' in deference to time-honored English usage. Here again we prefer the German practise.

The book will be useful, and while it has defects, it is the result of much painstaking work, and must prove helpful to other workers.

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DISCUSSION AND CORRESPONDENCE.

CURRENTS OF THE NORTH PACIFIC.

To the Editor of Science: I read with interest Dr. Bishop's letter on the source of the Pacific Coast current, and the hypothesis he proposes to account for it, in Science, of September 9.

The writer, like many others who have touched on ocean currents, does not make clear the distinction between the general system of oceanic circulation and ocean currents strictly so called.

The former is influenced by the rotation of the earth, differences of specific gravity and temperature in the oceanic mass, tides, the pressure of the atmosphere and various minor causes. The movement of Antarctic water northward in the Pacific belongs in this category, and we have no observations on record which would lead us to believe that the movement is other than very slow and gradual, or that it has any marked effect in producing the superficial streams of rapidly moving water which we call currents.

Oceanic currents are produced by the winds, by atmospheric pressure, and by the tides, modified by the presence of bodies of land. Permanent currents are due almost wholly to friction of permanent currents of air like the trade winds.

Dr. Bishop is quite right in supposing that the Kuro Siwo, like the Gulf Stream, does not extend across the ocean in which it originates. Nevertheless, the water of both, but especially of the Gulf Stream, has been traced thousands of miles beyond the point where the stream, *as a current,* has disappeared. It has been carried by the prevalent winds aided by the oceanic circulation.

The most complete collection of data for the North Pacific together with a discussion and chart may be found by Dr. Bishop in the report of the U. S. Coast Survey for 1880, Appendix No. 16, published in 1882, and to which little in the way of current data for the North Pacific has since been added.

The northwest trades, blowing hard and steadily for ten months in the year, carry the warm water, which the Kuro Siwo delivers in mid-ocean, to the northwest coast, which it

reaches about latitude 54° and there divides into a northerly and southerly stream. At this point the maximum temperature of the water is 68° F., but the average about 60° F. As it moves down the coast it loses its heat and produces the rains and fogs of the Oregonian region, cooling off so that when it reaches the latitude of the Golden Gate it has only the temperature of 54°, or thereabouts, and is colder than the normal sea water for that latitude. It continues southward as a cold current as described by Dr. Bishop. That this essentially superficial stream is not due directly to the impinging of cold Antarctic water on the northwest coast seems to be certain from the fact that the temperature of the latter is only 32° F., while the current, when it first reaches the coast, is thirty degrees or more warmer than that; and also that the water of the current is *warmer* in latitude 54° than it is in the more southern part of its course, whereas, if it was abyssal water we should expect it to be colder and to gradually warm up as it moved southward exposed to the action of the sun.

WM. H. DALL.

SMITHSONIAN INSTITUTION,
WASHINGTON, D. C.,
September 12, 1904.

SPECIAL ARTICLES.

ON THE PUPATION OF ANTS AND THE FEASIBILITY OF ESTABLISHING THE GUATEMALAN KELEP OR COTTON-WEEVIL ANT IN THE UNITED STATES.

IN a recent number of SCIENCE Dr. O. F. Cook publishes some of Mr. G. P. Goll's observations on the cocoon-formation of the kelep ant (*Ectatomma tuberculatum* Oliv.), apparently in the belief that similar observations have not been made on ants with enclosed pupæ. As a matter of fact, it has been known for some time that such ants bury their mature larvæ in the soil till they spin their cocoons and then, after some hours or days, unearth them and cleanse the outer surface of their envelopes. This habit has been repeatedly described for European species of *Formica*, especially by Wasmann.* It is, of course, a necessary habit, as pointed out by Dr. Cook, since the larva must have some support for the threads spun from its sericteries. In default of earth, as when ants (species of Camponotinæ or Ponerinæ) are kept in glass nests of the Fielde pattern, the workers tear off bits of sponge or toweling to spread over the larvæ as a support for the cocoon. If such materials can not be obtained, or if the larvæ are much disturbed while spinning, they will form free pupæ. I have seen this repeatedly in the case of mixed colonies of our American amazons (*Polyergus breviceps, P. bicolor* and *P. lucidus*) and their slaves, and in *Odontomachus clarus* and *Pachycondyla harpax* (a species allied to the kelep ant). The habit has been emphasized by Wasmann because it is of importance in his discovery of the interesting relations of *Formica* to the parasitic beetles *Lomechusa* and *Atemeles:*

> Both *Lomechusa* and *Atemeles* larvæ are assisted in their pupation by their hosts, exactly as are the ant larvæ. The adopted larva is placed on some soft sand, and while it moves the anterior portion of the body slowly to and fro, it is surrounded with a ring of earth, which is soon built over it like an arched roof. Within this the adopted larva spins a very fine web which merely keeps the surrounding sand particles together.
>
> This is the critical moment in the development of the *Atemeles* and *Lomechusa*. The ants are in the habit after a few days of unearthing their own larvæ which spin a dense, tough cocoon, in order to cleanse and stack up the cocoons. They attempt the same with the adopted larvæ, unfortunately, since they are thereby prevented from pupating and perish, if they are not again buried and left to themselves. Only such adopted larvæ develop, as are forgotten by the ants after they have been embedded. For this reason I obtained only one imago from thirty *Lomechusa* larvæ and not a single one from more than fifty *Atemeles* larvæ.

In this connection it is perhaps timely to call attention to the fact that C. Janet* some years ago emphasized the bearing of the presence and absence of the cocoon in ants on the

* See, *e. g.*, his 'Vergleichende Studien über Ameisen- und Termitengäste,' Haag, 1890, p. 95 *et al.*, up to his recent article: 'Zur Kontroverse über die psychischen Fähigkeiten der Ameisen,' *Natur und Schule*, Bd. 3, 1904.

* 'Les Fourmis,' *Soc. Zool. de France*, Conf. 28, Fév. 1896, Paris, 1896, pp. 3, 4.

theory of development by discontinuous variations, or mutations as they are now called:

> We are without doubt confronted in the ants with the disappearance of this protective envelope [the cocoon] which has become unnecessary through the incessant care lavished on the progeny by the workers.
>
> From the point of view of the evolution of instinct it is interesting to observe that this disappearance does not take place gradually by evanescence of the cocoon, but suddenly, so to speak, since larvæ which are similar to one another and produce similar adults, either make an absolutely complete cocoon, without any signs of reduction, or make none at all.
>
> This fact may be cited to show how sudden may be the changes that supervene in the habits of an animal. It supports the conclusions announced in a communication by my brother, M. Armand Janet, to the congress at Leyden. These conclusions, deduced from considerations of rational mechanics applied to the problem of species regarded as a position of equilibrium, tend to demonstrate that the differences between a certain form and its descendants are produced rather by quite sudden leaps than by insensible and continuous variations.

Much has been published of late, both by the government and the newspapers, concerning the advisability and feasibility of establishing the kelep ant in Texas and the other cotton-growing states for the purpose of destroying the boll-weevil. I feel at liberty to comment on this subject because for some years past I have had rather exceptional opportunities in Texas, Florida, Mexico and the Bahamas of studying the habits of a number of species belonging to the same natural subfamily as the kelep. This study has convinced me that the attempt to establish the ant in Texas will prove to be about as successful and profitable as an attempt to acclimatize in the same state some rare Central American orchid, the South African secretary bird or the Australian wombat. But in undertaking to give my reasons for this opinion, I am far from wishing that the experiment were not being tried. An experiment may, of course, be a complete failure from a purely economic standpoint and still be of considerable, albeit negative, scientific value.

At the outset I may say that I have not myself studied the living *Ectatomma tuberculatum*, though I am familiar with the insect in collections.* But Dr. Cook's account† shows that in all essential particulars its habits are the same as those of other Ponerinæ.‡

The peculiarities which the kelep shares with other Ponerinæ and which would seem to place serious obstacles in the way of establishing it in a foreign country, are the following:

1. The Ponerinæ are archaic ants which form small colonies§ and comprise no dominant species except in Australia, where the genus *Myrmecia* (the famous 'bull-dog ants') offers an interesting and instructive parallel to the marsupialia among mammals. In fact, the opossums of America bear about the same relation to our dominant mammals, like the rodents, as do the Ponerinæ to the dominant ants of the subfamilies Myrmicinæ and Camponotinæ.

2. The Ponerinæ are local and rare, and show little adaptability or plasticity in comparison with the more recently evolved and dominant species.

3. It is altogether exceptional for any of the Ponerinæ to restrict their diet to a single species of prey. In fact, the only known exception is the Texan *Leptogenys elongata*, which, as I have shown, feeds very largely, if not exclusively, on terrestrial isopods.¶ The kelep is described by Dr. Cook as capturing and consuming 'adult insects of many and diverse kinds,' so that we may be sure that it

* Dr. Cook is in error in supposing that there is anything doubtful about the occurrence of *E. tuberculatum* in Mexico. I have before me a fine series of workers taken at Tuxpan by Mr. J. F. McClendon. They agree perfectly with a typical specimen of the kelep collected by Stoll, at Retalhuleu, Guatemala, and sent me by Professor Forel.

† 'Report on the Habits of the Kelep, or Guatemalan Cotton-Boll-Weevil Ant,' U. S. Dept. Agr. Bur. Bull. No. 49, Washington, 1904.

‡ See my papers, 'A Study of Some Texan Ponerinæ,' *Biol. Bull.*, Vol. II., No. 1, 1900, and 'The Habits of *Ponera* and *Stigmatomma*,' *ibid.*, Vol. II., No. 2, 1900.

§ *E. tuberculatum* colonies contain from 20 to 110 workers each, and average between 40 and 50.

¶ 'A Crustacean-eating Ant (*Leptogenys elongata* Buckley),' *Biol. Bull.*, Vol. VI., 1904.

will not confine itself to boll-weevils, even if it succeeds in surviving the winters and floods of Texas. If we except a few vegetarian species like the curiously modified fungus-growing Attii, ants, like human beings, thrive best on a varied diet. Cook says that 'The discovery of the ant [the kelep] supplies a practical reason for the existence of the nectaries [of the cotton plant] hitherto quite unsuspected, and it suggests the further possibility that the weevil and the ant have been factors in the evolution of the cotton plant, for the weevil is not known to feed on any plant except cotton.' This statement is clearly at variance with the current views of many botanists and myrmecologists, who have compared the much exaggerated and largely fictitious accounts of the dependence of plants on protecting ants with the actual conditions.* Furthermore, even if we accept the views of Schimper and some other botanists in regard to the protection afforded plants by these insects, we should still be unable to understand why the boll-weevil was not long ago exterminated by the kelep, inasmuch as the beetle is clearly injurious to the cotton plant and hence to the supposed best interest of the ant.

The above considerations indicate that there is little probability that the kelep can be successfully established in Texas or adjoining states, or, if established, that it will be an appreciable factor in the extermination of the boll-weevil. This becomes even clearer if we glance for a moment at the more general subject of the introduction of ants into foreign countries. At first blush ants would seem to be the easiest of all insects to introduce, since the fertilized queen is long-lived and capable as an individual of producing a whole colony of all the three sexual forms so characteristic of these and other social insects. Moreover, the young brood is efficiently protected from danger by the workers and not left to shift for itself as in most insects. But when we come to enumerate the species that have been able to survive in foreign lands, we find it to be very small, limited to a few genera and comprising several more or less dubious cases. In my opinion the following are all the foreign ants that can be supposed to have established themselves in this country since it was opened up to commerce: *Tetramorium cæspitum, T. guineense* and *T. simillimum; Monomorium pharaonis, M. floricola; Pheidole megacephala, Prenolepis longicornis; P. pubens; Plagiolepis longipes,* and some doubt attaches to all of these forms except *M. pharaonis,* the tiny yellow house-ant of Old World origin. It is an open question whether *T. cæspitum* has been introduced into the United States. It seems to occur only along the Atlantic coast from Connecticut to Maryland, but it is quite possible that it may be indigenous. The remaining species in the above list are all tropicopolitan and may all be indigenous to the tropical and subtropical portions of our continent, for the conditions in these regions are much more generally favorable to ant-life than they are in temperate regions. All of these species are occasionally met with in our northern green-houses.*

Considering the ease with which incipient ant colonies and single fertilized queens are carried from one country to another in wood, hot-house plants, soil, minerals, etc., this list is surprisingly meager, even if there were sufficient evidence to prove that the species enumerated are all *bona fide* importations. Incidentally it should be noticed that none of these are Ponerinæ, but all belong to the two dominant subfamilies, the Myrmicinæ and Camponotinæ.†

One of the reasons for this small number of imported Formicidæ would seem to be the extreme sensitiveness of these insects to

* See, *e. g.*, the excellent article by Ernest Rettig, 'Ameisenpflanzen—Pflanzenameisen: Ein Beitrag zur Kenntnis der von Ameisen bewohnten Pflanzen und der Beziehungen zwischen beiden,' Jena, Gustav Fischer, 1904.

* Further study of *Formica cinerea* and *F. rufibarbis* convinces me that they can not have been imported from Europe, as I once supposed possible.

† Some idea of the number of species of ants accidentally introduced with hot-house plants at a single port (Hamburg), may be obtained from two of Forel's recent papers: 'Fourmis Importées,' *Bull. Soc. Ent. Suisse.*, Vol. 10, 7, pp. 284–287, 1900, and 'Formiciden des Naturhistorischen Museums zu Hamburg, *Mitth. a. d. Naturhist. Mus.*, 18, 1901. Anhang., pp. 78–82.

physical conditions such as soil, moisture, sunlight, etc. No animals exhibit finer geographical variations or depend more completely on a very precise environment. While a certain and even considerable range of adaptability to varying conditions undoubtedly exists in many of the species, this is confined to dominant forms, like certain Myrmicinæ and Camponotinæ, and does not extend to the archaic and relict Ponerinæ, even the most variable of which, like *Odontomachus,* are peculiarly specialized and lacking in plasticity.

But even if the physical conditions of Texas and the other southern states prove to be favorable, it is certain that the kelep will have to reckon with the ant fauna already existing in this region, and in no state of the union is this so extensive and so formidable as in Texas. It is, indeed, probable that the living will be an even greater danger than the physical environment to a species which is very far from being a dominant faunal component even in its native land.

Dr. Cook makes the statement that 'the kelep is as yet the only ant known to attack and destroy healthy boll-weevils.' A few years ago Professor A. Herrera, of the City of Mexico, sent me for identification a species of ant which he found attacking the boll-weevil. I am not sure that he has published any observations on this insect,* which occurs from Colorado through Texas into Mexico, but seems not to be found east of the Pecos River. It may be seen at its best at Fort Davis, Texas, where it forms enormous colonies in grassy places about the cotton wood trees along the arroyos. Although it is extremely predatory and pugnacious, it does not sting. Of course, it is doubtful whether this ant could be induced to live in the cotton-growing portions of Texas, but it seems to me that it would be a better form for experimentation than the kelep, if, as Professor Herrera seems to have found, it really attacks the boll-weevil.

William Morton Wheeler.

American Museum of Natural History,
September 5, 1904.

* Described by me as *Formica subpolita* Mayr var. *perpilosa. Mem. y Rev. de la Soc. Cient.,* 'Antonio Alzate,' Vol. 17, 1902, p. 141.

CURRENT NOTES ON METEOROLOGY.

GENERAL CIRCULATION OF THE ATMOSPHERE.

Dr. W. N. Shaw read a paper on the 'General Circulation of the Atmosphere in Middle and Higher Latitudes' before the Royal Society, on June 2, which he summarizes in *Nature* for July 7. The isobars computed by de Bort for 4,000 meters above sea level indicate a comparatively simple steady motion around the polar axis from west to east, somewhat deflected to south or north by land or sea areas. The computed velocities of air movement on the gradients at this level are not at all unreasonable, and the directions of motion are appropriate, and are confirmed in Hildebrandsson's report on cloud motion. When the weight of the stratum of air between 4,000 meters and sea level is charted by means of sea level isobars, a circulation of the atmosphere from east to west around the cold pole in each hemisphere is indicated. The general surface pressures may, therefore, be resolved into two components, one due to the upper stratum above 4,000 meters which, alone, would produce a general circulation from west to east around the minima of pressure near the poles. The other, due to the lower stratum, if acting alone would produce a circulation from east to west. Both circulations would correspond closely with the surface distribution of isotherms. Where the one is predominant, in the lower middle latitudes, we get a resultant westerly circulation; where the other is predominant, near the poles of cold, we get an easterly circulation. And between the two there is a region of minimum pressure and a merging of the two circulations, which gives rise to the cyclonic storms of the north and south temperate zones. In the lower air the caps of relatively cold air in the polar regions stop the westerly currents which still flow in the lower latitudes, and replace them by currents from the east. Between these two currents mixing takes place, and eddies may be formed.

JAPANESE METEOROLOGICAL OBSERVATORY.

Bulletin No. 1 (1904) of the Central Meteorological Observatory of Japan, contains the following papers: 'Observations of the Earth

Temperature at Tokio,' by W. Oishi, based on the records taken between 1886 and 1902; 'Température moyenne annuelle de la Surface de la Mer dans l'Océan Pacifique Occidental,' by Y. Wada, based on observations from 1882 to 1901, and illustrated by means of monthly and annual isothermal charts; 'The Epochs of the First Ice in Japan for 1902,' by T. Okada, with a chart; and 'Evaporation in Japan,' by T. Okada, which is a contribution of considerable general interest and importance. The present *Bulletin* is the first of a series of publications which are to appear under the title *Bulletins of the Central Meteorological Observatory of Japan.* These bulletins are to be issued at convenient intervals, and are to contain the results of researches on meteorology and allied sciences made by the members of the observatory. It is intended that observations, and their discussion, on special subjects not included in the routine work of the service, shall also be published. The present volume, with the promise of those issues which are to follow later, indicates a high degree of activity in meteorological work in Japan.

VIENNA METEOROLOGICAL OBSERVATORY.

THE annual volume of the *Central-Anstalt für Meteorologie und Erdmagnetismus* in Vienna (1902, date of publication 1904) gives evidence of a constantly expanding sphere of activity of this observatory, under the able directorship of Dr. J. M. Pernter. Among the noteworthy data contained in this publication are the results obtained by means of self-recording instruments on the Sonnblick and Obir (two stations); at Tragöss, the interesting 'North Foehn' station; at Beirut, Jerusalem and Port-au-Prince. Dr. Felix M. Exner has been taken on to the regular staff of the central observatory, and has also recently been appointed *Privat Docent* in meteorology at the University of Vienna. Dr. Exner recently spent several weeks in the United States, making a study of our meteorological equipment at Washington, Blue Hill and other places, and of the methods and illustrations employed in teaching meteorology at Harvard and elsewhere. His work in teaching at Vienna will help to give that city added prestige as a meteorological and climatological center. A supplement to the present volume, which was published some months ago, deals with the question of 'weather shooting,' and was reviewed in these columns.

MOUNTAIN SICKNESS.

Mosso, who has made a considerable study of the physiological effect of higher altitudes, contributed two papers to the *Atti dei Lincei,* for June 19 last, which, according to the abstract published in *Nature,* of August 4, tend to disprove the assumption that the difficulties experienced are due solely to the diminished tension of the oxygen in the air. Mosso now shows that when the barometric pressure of a mixture of oxygen and nitrogen is diminished to one third of an atmosphere, while the proportion of oxygen is increased until its partial pressure is the same as under ordinary circumstances, severe inconvenience, abnormal respiration and pulse action result. That this is not due merely to the increased proportion of oxygen has been shown by a study of the effects produced by breathing pure oxygen on the summit of Monte Rosa. Blood analyses indicate that a diminution in the proportion of carbon dioxide, caused by the low pressure, is probably responsible for the result. This view is upheld by the fact that a mixture of oxygen and carbon dioxide, containing 20 per cent. of the latter, which resulted in dizziness and nausea when breathed at Turin, was attended by sensations of ease and pleasure when breathed on Monte Rosa.

R. DEC. WARD.

NOTES ON INORGANIC CHEMISTRY.

CONDITION OF HELIUM IN PITCHBLENDE.

R. J. Moss recounts in the *Comptes Rendus* an attempt to determine the condition in which helium exists in pitchblende. The mineral was powdered in a vacuum. The chief substance set free was water vapor, and it was accompanied by small quantities of helium, carbon dioxid, nitrogen and oxygen. While about one half of the gas set free, exclusive of water, was often helium, yet the

amount was only about one per cent. of the total helium in the mineral. In one instance 0.7 per cent. of the gas obtained was hydrogen, which Moss thinks may have been the product of the action of radium upon the water present. The conclusion drawn is that the helium exists in pitchblende in a free state, enclosed in exceedingly small cavities.

HELIUM IN MINERALS FROM GREENLAND.

An investigation has been made by Julius Thomsen of the gases contained in a fluorspar from Greenland, containing fluorids of the rare earths. At a red heat a kilo of the spar gave off about 800 cubic centimeters of gas, 715 of which were carbon dioxid, probably due to the presence of ferrous carbonate. The other 85 cubic centimeters consisted of hydrogen, carbon monoxid, hydrocarbons and 24–27 cubic centimeters of helium. When the mineral was treated, prior to heating, with hydrochloric or nitric acid, or both, while the carbon dioxid was reduced to about 40 cubic centimeters, the amount of helium remained unchanged. The same was true even after treatment with concentrated sulfuric acid, or fusion with caustic potash. From these experiments Thomsen concludes that if the helium is not free, it must be present in an extraordinarily firm compound. Other minerals from Greenland containing rare earths were also examined, including steenstrupite, eudialyte and a silicate from Ivigtut, and while much gas was often evolved, no trace of helium was found. The same was true of a green fluorspar from England, which gave on heating a blue fluorescence.

CONDUCTIVITY OF RADIUM SOLUTIONS.

It would not be surprising, in view of the ionizing power and high atomic weight of radium, if its salts showed an abnormal conductivity in solution, but recent experiments of Kohlrausch and Henning indicate that this is not the case. Assuming the atomic weight of radium as 225 and working with about 8 milligrams of the bromid, they find the molecular conductivity and the migration velocity of the radium ion to be very close to that of barium, and not far from that of strontium and calcium. If the atomic weight of radium be 258, as claimed by Runge and Precht, these values become only a little higher. They consider this as a new example of the small part played by the atomic weight in determining the characteristics of a salt.

METALS IN MINERAL WATERS.

Much has been written on the therapeutic action of the heavy metals in mineral waters, and a new suggestion has been put forward by Garrigou in the *Comptes Rendus*. After submitting the water of the old Eaux-Bonnes spring to prolonged dialysis, he finds the larger part of the heavy metals in the undialyzable portion; that is, they are present in a colloidal form, doubtless in organic combination. He considers that these metallic compounds are of the nature of oxydases and play an important part in the therapeutics of mineral water. This discovery would seem also to be of importance in water analysis, since these metals would not react with the ordinary reagents for metals in solutions, and complete destruction of all organic matter in the water would thus be an indispensable preliminary step before the determination of at least any heavy metals.

ACTION OF METALS ON FERMENTATON.

An interesting series of experiments by Leopold Nathan are described in the *Centralblatt für Bakteriologie und Parisitenkunde*, made in the effort to determine how far metals and metal containers have an inhibitory action upon fermentation processes. The experiments were carried out by immersing pure metals in the form of thin cylinders in the fermenting liquid. Both cider and beer were used. In the case of cider, in general more of the metal passed into solution, but the ferment was more resistant. The liquid remained clear during and after the fermentation. Beer was much more sensitive. With the iron cylinder, a grayish sheen was visible in the liquid, which during the fermentation became inky, and finally a black precipitate appeared. German silver, copper, zinc, brass and bronze had a decidedly strong inhibitory action upon the fermentation, while tin and

lead were moderately toxic. On the other hand, polished iron, silver, gold, polished tin, aluminum, nickel and a few alloys, as well as celluloid, glass, and hard rubber, had little or no effect. In metals, the smoothness of surface seems to have a decided influence.

BIOCHEMICAL REACTIONS FOR TELLURIUM AND SELENIUM.

IT has long been known that certain micro-organisms are capable not only of living in arsenic solutions, but of reducing arsenic compounds to volatile gases containing arsenic. It has indeed been supposed by many that the chief danger to be apprehended from arsenical wall papers is the production of such poisonous gases by molds. This study has been applied by Professor Gosio, of Rome, to compounds of tellurium and selenium, chiefly to tellurites and selenites. The former are much more susceptible to the action of micro-organisms than arsenic compounds, showing a decided brown or violet coloration with *Hyphomycetes* under favorable circumstances within two or three minutes. The tellurites also react with the *Schizomycetes* and various bacteria, often giving black precipitates. The compounds formed depend upon the particular kind of microorganism used. The selenites are decomposed almost as rapidly, giving with cultures of the colon bacillus a red coloration in six minutes. The coloration is probably due to the precipitation of metallic selenium. These reactions are suggested for the purpose of detecting certain microorganisms.

SOURCE OF NORMAL ARSENIC IN THE BODY.

Now that it is well established that arsenic is a normal constituent of the human body, it becomes of interest to know its source, and this problem has been studied by Gautier, to whom we owe so much of our knowledge regarding the detection and determination of minute quantities of arsenic. In conjunction with Clausmann he has analyzed a large number of foods, and the following are some of his results. The figures represent the number of micrograms (= 0.001 milligram) in 100 grams of substance; that is, parts per million.

Fresh beef	0.7–0.8
Fresh veal	0.5–1
Milk	less than 0.05
White of egg	none
Yolk of egg	0.5
Mackerel	2.7–3.9
Crab, muscle	2.2
" egg and fat	35.7
" shell	104
" whole animal	45.3
Corn	0.7–0.85
Wheat bread	0.71
Cabbage	0.2
String beans	none
Potatoes	1.12
Burgundy wine	0.27
Beer	0.01
Water of the Seine	0.5
Sea water, surface	1.1
" " 10 meters deep	2.5
White salt	0.7
English salt	15
Gray salt	45
Rock salt	14
" " from Stassfurt	2.6

Gautier draws the following conclusions: Muscle contains very little arsenic in comparison with certain organs, and this can be considered as circulating rather than fixed arsenic; great variations are found in the flesh of the same species of animal, in fish unquestionably due to the varying arsenic of the sea and to the food; of man's food, certain fish and crustaceans, and gray salt are richest in arsenic, but in general the chief sources are wine, water and salt; some foods contain no trace of arsenic, so that it can not be held that arsenic is universally present, or that it is a constant constituent of the living cell. From Parisian statistics for ten years, it may be considered that a man ingests 20.9 micrograms of arsenic per day, or 7.66 milligrams per year. In medico-legal cases, it is recommended that only such organs as normally contain arsenic merely in traces, be examined, as the liver, spleen, muscle and washed intestine. If the contents of the intestine show more than one tenth of a milligram of arsenic, we may be sure it did not come from normal food.

J. L. H.

BOTANY AT THE CUBAN EXPERIMENT STATION.

The organization of the botanical work at the Estacion Central Agronomica de Cuba is now far enough advanced to justify a brief account of our facilities and plans for future work. At least three of the departments of the station will be of interest to botanists. The horticultural department is under the charge of Professor C. F. Austin, late of the Maryland Agricultural Experiment Station, with E. W. Halstead, of New Mexico, as assistant. Among the interesting lines of work begun by this department may be mentioned the trial of a large line of temperate fruits, vegetables and ornamentals in order to note their behavior under tropical conditions and to determine which among them can be profitably grown in Cuba. The native Cuban varieties will also be collected and grown for the purpose of comparative studies and to furnish the basis for the selection of improved strains. Attention will be given to the introduction of promising novelties from other tropical countries with a view to building up a living collection of as many as possible of the economic plants that will thrive under the conditions prevailing at this place. This department too will be charged with the care of the living collections of Cuban plants that are of botanical interest only. It is hoped in the course of time to have living specimens of many of the more interesting native plants. An abundance of land is available for these purposes, and propagating sheds, cheese-cloth tents and other appliances are being provided.

The department of vegetable pathology is of course largely botanical, though as here constituted it includes economic entomology. It is in charge of Dr. Mel T. Cook, of Indiana, with Mr. W. T. Horne, of Nebraska, as assistant. The department is provided with a roomy laboratory which is to be shared by the bacteriologist of the animal industry department. It is equipped with the necessary apparatus for rearing and studying disease-producing organisms of all kinds, whether animal or vegetable, including the usual list of glassware, sterilizers, incubators, microtomes and microscopes, besides a complete Zeiss micro-photographic outfit.

The botanical department proper is in charge of Professor C. F. Baker, of Pomona College, California, with Mr. Percy Wilson, of the New York Botanical Garden, as assistant. It is provided with an abundance of room for laboratory and museum purposes. The furnishings include herbarium cases of native hard-woods. The library already contains many of the more important general works, and a special effort is being made to get together as complete a collection as possible of books relating to tropical American botany. The private libraries of Professor Baker and of the writer are also on deposit and are accessible. These include several thousand additional titles. Through the generosity of the New York Botanical Garden and the purchase of Mr. Heller's private collection of West Indian plants, the herbarium already comprises several thousand mounted sheets of West Indian plants that have been determined at the leading herbaria. According to arrangements with Professor Baker, his private herbarium containing over a hundred thousand specimens is deposited at the station and is available for study. This collection is notably rich in tropical American plants containing more or less complete sets of the collections of Sentenis and Heller in Porto Rico; Otto in Trinidad and Cuba; Ehrenberg, Pringle, Schiede, Seler and Purpus in Mexico; Brandegee in Lower California; Baker in Nicaragua; Moritz in Colombia; Schomburgh in Guiana, and Sello in Brazil. Work in collecting the local flora has been actively pushed since the first of July, and much valuable material has already been secured. Plans are being matured for extending this work to other parts of the island in the near future. Particular attention will, of course, be given to all questions connected with economic botany, including forestry problems, study of the native grasses and legumes and of troublesome weeds, and the gathering together for the living collections of native medicinal plants or those yielding fibers, resins, gums or other possible commercial products. At all times, however, the work will be directed towards a

complete botanical survey of the island, since the fact is fully appreciated that the natural plant covering of a region is closely correlated with its agricultural possibilities. As one of the results of this survey it is planned to publish an illustrated flora of Cuba. Work towards that end has already been begun, and it is proposed to prosecute it as rapidly as circumstances will permit. In this connection it will be necessary for the botanist to visit the larger American and European herbaria where types of Cuban plants are likely to be found.

There are, however, numerous smaller collections, both public and private, which contain interesting Cuban material. Where it is possible to secure the loan of such material it will be thankfully received and carefully returned. A large quantity of duplicate material is being collected with which to repay such courtesies and to offer in exchange for other tropical American plants. It will not, however, be the policy of this institution to offer sets of such material for sale.

An available tropical laboratory has long been the dream of American botanists. Within the last few months this dream has been realized by the arrangement between the Jamaican government and the New York Botanical Garden for the use of the Cinchona plantations. It is now possible to offer the use of a second tropical laboratory. We feel that the occasional residence among us of active botanists from other institutions, bringing, as they will, fresh suggestions and inspiration, would be of the greatest benefit to us. We, therefore, freely offer the use of our facilities to any properly accredited botanist who cares to make use of them for any line of botanical investigation, stipulating only that arrangements be made long enough in advance to avoid possible conflicts. Persons desiring to do much microscopic work should bring their own instruments with them. Santiago de las Vegas is situated twelve miles south of Havana in a rolling, open country. There are four trains a day to and from Havana over the Western Railroad. The elevation is only about one hundred and fifty feet. The conditions are, therefore, absolutely different from those in Cinchona with its rugged mountains and five thousand feet of elevation, and a residence at one of them will only sharpen the appetite for experiences at the other.

F. S. EARLE,
Director Cuban Experiment Station.

THE INTERNATIONAL CONGRESS OF ARTS AND SCIENCE.

WE hope to print later an account of the work of the International Congress of Arts and Science, held last week at St. Louis, and we have already printed the program and a description of the aims of the congress by Professor Münsterberg, who was chiefly responsible for its plan. In the last issue will be found the address of the president and in this issue the address before the department of physical science; others of the important addresses will appear subsequently. These articles and addresses give an adequate impression of the work of the congress, and only a few words are needed at this time.

It was the unanimous opinion of nearly all those present that the congress was successful and successful beyond the anticipations that had been formed. There has perhaps never been assembled together a group of scholars so notable, and the addresses were real and in some cases important contributions to science. With the possible exception of the 'Encyclopædia Britannica,' the addresses when published together will give the best review that has ever appeared of contemporary science and scholarship. There were about a hundred foreign delegates, each a leader in his science. A selection of names must be almost at random, but it may be questioned whether there were ever before gathered together in one room men of science and scholars so eminent as Poincaré, Darboux, Picard, Boltzmann, Ostwald, van't Hoff, Ramsay, Moissan, Backlund, Arrhenius, Murray, Penck, Zirkel, de Vries, Giard, Delage, Hertwig, Waldeyer, Seler, Höff-

ding, Erdmann, Ward, Liebreich, Kitasato, Semon, Escherlich, Rein, Lamprecht, Conrad, Furwängler, Harnack, Brunialti and Bryce. The American speakers and chairman formed a group of leaders in scientific research, of whom any country might be proud.

A congress of arts and science gives distinction to a universal exposition, but no one supposes that it is the most suitable place for such a meeting. There are many material difficulties which were by no means overcome at St. Louis. The audiences averaged about a hundred—though in one case at least there were only five hearers present—but they were not composed chiefly of scientific men. Criticism should, however, be overshadowed by appreciation. Never before has an attempt been made to give such a complete and unified summary of the progress of science. President Francis, Mr. Rogers, Mr. Schiff and other officers of the exposition deserve thanks and honor for their interest in the congress; President Butler and other members of the administrative board, for the general arrangements, and Professors Newcomb, the president, Münsterberg and Small, the vice-presidents, for the work of organization.

SCIENTIFIC NOTES AND NEWS.

The honorary vice-presidents of the International Congress of Arts and Science were the Hon. James Bryce, Great Britain; M. Gaston Darboux, France; Professor Wilhelm Waldeyer, Germany; Dr. Oskar Backlund, Russia; Professor Theodore Escherich, Austria; Signor Attilio Brunialti, Italy. The executive secretary of the congress was Dr. L. O. Howard, permanent secretary of the American Association for the Advancement of Science.

Captain Scott and the officers and men of the *Discovery* were welcomed at the East India dock by luncheon on their arrival on September 16, the invitations being sent by the presidents of the Royal and the Royal Geographical Societies. In the evening Captain Scott and the officers were entertained at a dinner given by the Royal Geographical Society. Addresses were made by Sir Clements Markham, president of the Royal Geographical Society, Captain Scott and others.

The Medical and Chirurgical Faculty of Maryland has asked Professor William Osler to sit for a portrait to be placed in the hall of the faculty in Baltimore. It is stated that Professor Osler will not sever his connection with the Johns Hopkins University until after the end of the present session.

Dr. Benno Erdmann, professor of philosophy at the University of Bonn, who gave one of the addresses at the St. Louis Congress, celebrated the twenty-fifth anniversary of his professorate on August 29.

Dr. James Ward, professor of moral philosophy and logic, at Cambridge University, gave the annual address before the Philosophical Union of the University of California, on August 26.

Professor Cleveland Abbe, of the U. S. Weather Bureau, delivered an address on 'Instruction and Research by Weather Bureau Officials' at the recent session of the United States Weather Bureau Officials at Peoria.

Dr. Aug. Wassermann, titular professor of internal medicine and bacteriology at the University of Berlin, gave an address on 'The Theory and Practise of Immunity,' before a special meeting of the New York Pathological Society, on September 28.

Dr. Ronald Ross, of the Liverpool School of Tropical Medicine, who is at present in the United States as delegate to the recent Congress of Arts and Science at St. Louis, will proceed to Panama as guest of the Canal Commission.

Professor F. H. Herrick, professor of biology at Western Reserve University, has returned to the United States after a year's absence in Europe.

The British chancelor of the exchequer has appointed the following gentlemen to serve as members of a committee to inquire into the use of duty-free alcohol for industrial pur-

poses: Sir Henry Primrose, K.C.B., C.S.I., chairman; Sir William Crookes, F.R.S.; Sir W. H. Holland, M.P.; the Hon. J. Scott-Montagu, M.P.; Mr. Lothian D. Nicholson; Dr. W. Somerville; Dr. T. E. Thorpe, C.B., F.R.S.; and Mr. Thomas Tyrer.

AMONG those invited to lecture in the annual course of public lectures on 'Contemporary Educational Problems,' given by Teachers College, Columbia University, are Dr. John H. Finley, president of the College of the City of New York; Mr. St. Clair McKelway; Professor Liberty H. Bailey, dean of the College of Agriculture, Cornell University; Dr. Henry M. Leipziger, supervisor of lectures, New York City; Professor Felix Adler; Dr. Walter H. Page, editor of the *World's Work,* and Mr. Wallace H. Buttrick, executive secretary of the General Educational Board.

THE autumn lectures of the New York Botanical Garden will be delivered in the lecture hall of the museum building of the garden, Bronx Park, on Saturday afternoons, at 4:30 o'clock, as follows:

October 1, 'The Origin of Species as illustrated by the Evening Primrose,' by Professor Hugo de Vries.

October 8, 'The Botanical Exploration of the Bahamas,' by Dr. N. L. Britton.

October 15, 'A Summer at the Desert Laboratory,' by Professor Francis E. Lloyd.

October 22, 'Botanizing in the Austrian Tyrol,' by Dr. W. A. Murrill.

October 29, 'Life-History of a Fern,' by Professor L. M. Underwood.

November 5, 'Fossil Plants of the Vicinity of New York,' by Dr. Arthur Hollick.

November 12, 'The Effect of Wounding on Plants,' by Professor H. M. Richards.

November 19, 'Hybrids; Their Nature and Behavior,' by Dr. D. T. MacDougal.

A SERIES of nine lectures on science and travel has been arranged by the Field Columbian Museum at 3 o'clock on Saturday afternoons during October and November. The program is as follows:

October 1, 'Wild Flowers of the Chicago Basin,' Dr. C. F. Millspaugh, curator of botany.

October 8, 'Japan—Land of Lacquer and Bamboo,' Dr. C. F. Millsbaugh, curator of botany.

October 15, 'Variation of Birds,' Dr. N. Dearborn, department of ornithology.

October 22, 'Crystals,' Dr. O. C. Farrington, curator of geology.

October 29, 'Wyandotte and Marengo caves,' Dr. O. C. Farrington, curator of geology.

November 5, 'A Naturalist in Africa—Field Columbian Museum Expedition,' Professor D. G. Elliot, F.R.S.E., curator of zoology.

November 12, 'Cats and the Lands they Inhabit,' Professor D. G. Elliot, F.R.S.E., curator of zoology.

November 19, 'The Decorative Art of the North American Indians'—Part 1, Dr. G. A. Dorsey, curator of anthropology.

November 26, 'The Decorative Art of the North American Indians'—Part 2, Dr. G. A. Dorsey, curator of anthropology.

AT a business meeting of the Elisha Mitchell Society of the University of North Carolina, held on September 12, the following officers were elected:

President—Professor Wm. Cain.
Vice-President—Professor J. E. Mills.
Corresponding Secretary—President F. P. Venable.
Recording Secretary—Professor A. S. Wheeler.
Editorial Committee—Professor W. C. Coker, Professor J. E. Latta, Professor A. Henderson.

PROFESSOR NILS FINSSEN, of Copenhagen, known for his discovery of the light cure for lupus, died on September 24.

KARL FREIHERR V. ERLANGER, the African explorer, has died at the age of thirty-two years.

IN a recent address before the Royal Geographical Society of London, the president, Sir Clements Markham, stated that the work of the society had so greatly increased that it would be necessary to move into a larger building. A good sum had been offered for the present house, but in addition to that sum a far larger amount would be required to obtain a freehold site and erect a suitable building. Several sites had been offered, but the council did not feel justified in taking further steps until most of the amount required (about $600,000) had been subscribed. In the meantime a special committee is considering the question of increasing the accommodations.

CABLEGRAMS to the daily papers report an eruption of Mt. Vesuvius more violent than any since 1872. The upper station of the fu-

nicular railway has been destroyed and the metal of the tracks has been melted.

The *British Medical Journal* states that an examination by Professor Dunstan at the Imperial Institute, London, of certain minerals discovered during the recent mineralogical survey of Ceylon has shown that the principal constituent of one found in refuse from gem washings near Belangoda is radio-active; it contains 75 per cent. of thorium oxide, and it is thought probable that radium is present.

Professor James Beart Simonds, of the Isle of Wight, has bequeathed his veterinary specimens and library of veterinary and scientific works to the Royal Veterinary College, London.

It is reported that Dr. Theodore Koch, of the Berlin Museum für Völkerkunde, who is exploring the districts of the Upper Amazon, reports that he has advanced farther than any white man on the Rio Tiqui, and has come into contact with hitherto unknown Indian tribes. He spent several weeks in their villages, and has brought back from his journey a rich collection of photographs and native articles, among others the famous signal drum of the Tukano tribe. He hopes to prolong his operations till the spring of next year, but the continued disputes between the Peruvians and Brazilians have somewhat interfered with his arrangements.

UNIVERSITY AND EDUCATIONAL NEWS.

The late Professor Daniel Willard Fiske has bequeathed the main part of his estate to Cornell University. It is said that the bequest amounts to between $500,000 to $1,000,000. It will be remembered that Professor Fiske's wife, who died some two years ago, left $2,000,000 to Cornell University, but that the will was broken by Professor Fiske.

The main building of the University of Minnesota was destroyed by fire on September 24, entailing a loss of $125,000 which is said to be covered by insurance.

Sir Alfred Jones has given £500 and Mr. John Holt £200 to the Liverpool School of Tropical Medicine for a fund to be known as the Sir William MacGregor Fund, in honor of the newly appointed governor of Newfoundland.

The presidency of Tulane University has been offered to Dr. E. B. Copeland, president of the Missouri State Normal School, Warrensburg, Mo.

Dr. Adolf Meyer, of the N. Y. State Pathological Institute, has been appointed professor of psychiatry in the Cornell University Medical School in the place of Dr. Allan McLane Hamilton, who recently resigned.

The lectureship of pathological chemistry, at New York University, recently endowed by Dr. C. A. Herter, will be held during the present year by Dr. P. A. Levene, of the N. Y. State Pathological Institute.

The following appointments have been made at Lehigh University: Winter L. Wilson, C.E., M.S., Lehigh, '88, and recently professor of civil engineering in Tulane University, assistant professor in civil engineering; Sherman M. Turrill, C.E., Cornell, '91, and Robert W. Gay, B.S., C.E., New York University, instructors in civil engineering; Arthur W. Klein, M.E., Lehigh, '99, and Evert O. Eastwood, A.M., B.S., University of Virginia, and Massachusetts Institute of Technology, instructors in civil engineering. Other new instructors are Charles W. Brown, A.M., Brown University and Harvard, in the department of geology; Stanley S. Seyfert, E. E. Lehigh, '04, electrical engineering; George C. Beck, A.C., Lehigh, '04, assistant in chemistry.

Lorande Loss Woodruff, A.M. (Columbia), has been advanced to an instructorship in biology at Williams College.

At Dartmouth College, the following appointments have been made: *Mathematics,* C. A. Holden, assistant professor; Mr. Barton, instructor; *Biology,* Mr. Lyman, instructor in biology (botany), made assistant professor; *Medical School,* Dr. Percy Bartlett, A.B., Bowdoin, '92, M.D., Dartmouth, '00, instructor in anatomy; Dr. C. C. Stewart, assistant professor of physiology, Pennsylvania, assistant professor of physiology.

Dr. Hermann Kossel, of the Imperial Board of Health at Berlin, has been called to the chair of hygiene at the University of Giessen, as the successor of Dr. Georg Gaffky.